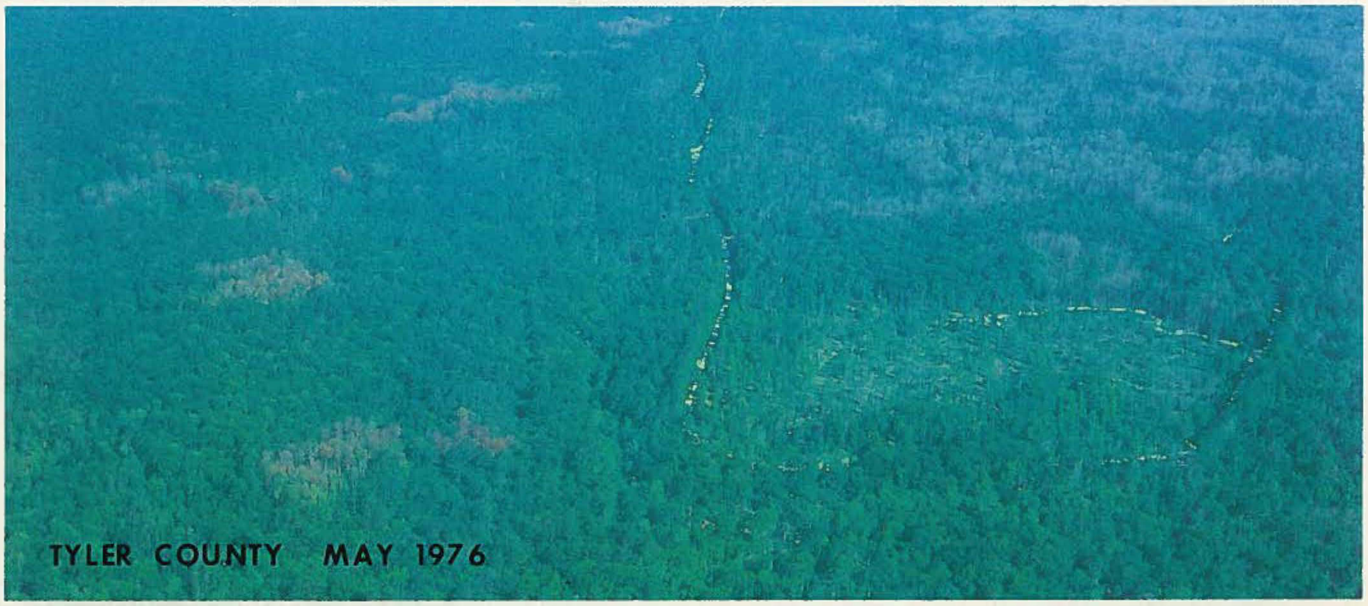
Texas Forest Pest Activity 1976 - 1977
and
Forest Pest Control Section Biennial Report



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TEXAS FOREST SERVICE

A Part of

The Texas A&M University System

cover:

The potential of southern pine beetle infestations to expand if not controlled is illustrated by these two sequential photographs taken 5 months apart in the Beech Creek Unit of the Big Thicket National Preserve (Tyler County) during 1976.

Texas Forest Pest Activity
1976 - 1977
and
Forest Pest Control Section
Biennial Report

With Cooperation From
Private Forest Industry
and
National Forests in Texas

TEXAS FOREST SERVICE
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INTRODUCTION

Since 1967 the Forest Pest Control Section of the Texas Forest Service has published a periodic status report of pest activity in the forests of East Texas. The report was expanded in 1974 to include a biennial synopsis of research activities, personnel changes, and recent developments concerning the Pest Control Section. Much of the information on pest activity, damage and losses has been provided by private forest industry and the National Forests in Texas. Their cooperation is gratefully acknowledged.

Texas Forest Pest Activity 1976-1977

Southern Pine Beetle

Historically, the southern pine beetle, *Dendroctonus frontalis,* has been the major pest problem in the forests of East Texas, causing significant timber losses for some 20 consecutive years. The past two years were no exception. In fact, the current beetle outbreak reached record levels throughout East Texas in 1976. Fortunately, beetle populations declined to relatively low levels during 1977. Decreasing population trends also were apparent in most other southern states.

Southwide Infestation Status

The southern pine beetle (SPB), native to the southern pine regions of the United States and parts of Central America, is considered the most destructive forest insect pest in the South. The Southeastern Area office of the U.S. Forest Service in Atlanta, Ga., maintains records on SPB activity and associated timber losses for the 13 southern states. They report that, with the exception of Mississippi, all states involved in the most recent outbreak (1973-1976) experienced reduced beetle activity during 1977.

Federal funds spent for SPB control on the National Forests in the 13 southern states totaled $1,105,613 during fiscal year 1976, with a reduction to $499,179 in fiscal year 1977. On state and private lands in this same 13 state area, federal funds amounting to $843,624 and $589,077 were spent on SPB control programs for FY 1976 and FY 1977, respectively. The reduced spending in 1977 reflects the general decrease in SPB activity.

The volume of beetle-infested timber that was salvaged south-wide during 1976 was estimated to be 14,016,000 cubic feet of pulpwood and 246,000,000 board feet of sawtimber from the 13 states. During 1977, salvage programs were conducted in only 5 states, accounting for 6,117,000 cubic feet of pulpwood and 98,000,000 board feet of sawtimber. Seldom, if ever, is it possible to salvage all beetle-killed trees; therefore these salvage figures only partially reflect the total impact of this pest.

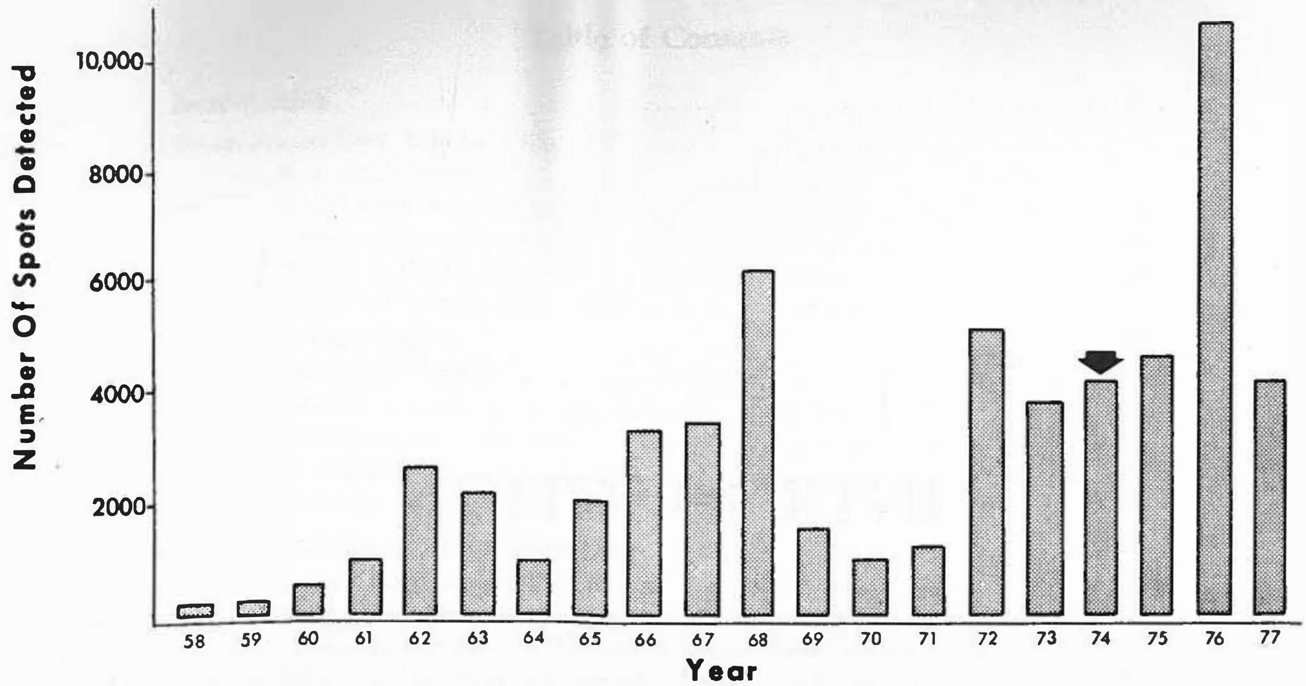


Figure 1. Total number of southern pine beetle spots detected in East Texas from 1958-1977. Minimum spot size for detection purposes was increased from 5 to 10 trees beginning in 1974 (◆).

Status in East Texas 1976

The bicentennial year of 1976 also was a landmark year in East Texas for the southern pine beetle. The total number of SPB infestations (spots) as well as beetle-caused timber losses during 1976 were the greatest ever recorded in East Texas. A total of 10,926 spots ($\geq$ 10 trees) was detected in 1976 (Fig. 1), nearly double that for any previous year on record. An estimated 41,000 acres of pine timber were killed, amounting to a stumpage value (salvaged and non-salvaged) of close to $17,000,000. By comparison, the acreage of SPB-killed timber during 1974 and 1975 combined was only 15,000 acres. The total volume of timber killed on state and private lands in 1976 was estimated to be 51,619,000 cubic feet, over half the accumulated total volume of pine timber infested by SPB in East Texas for the entire 18-year period 1958-1975 (Table 1). These figures do not include losses on National Forests (see salvage figures on page 8) nor the more than 3,500 acres of pine timber killed on recently designated units of the Big Thicket National Preserve in southeast Texas.

During most years, detection of new SPB infestations occurs primarily during the months of May, June and July, and declines markedly by August. However, as shown in Fig. 2, new spots continued to appear at a high rate throughout August, September and October of 1976. Apparent reasons for the increased beetle activity and severe losses ex-

Table 1. Estimated Volume of Pine Timber Killed by the Southern Pine Beetle in East Texas Since 1958.

Year	Sawlogs (M bd. ft.)	Pulpwood (cords)	Total (M cu. ft.)
1958	500	0	84
1959	2,500	2,500	598
1960	8,000	8,000	1,912
1961	17,887	24,000	4,715
1962	93,043	111,110	23,538
1963	4,084	1,920	820
1964	2,501	1,420	520
1965	3,797	7,743	1,192
1966	6,256	6,930	1,544
1967	7,194	8,566	1,818
1968	17,644	22,037	4,533
1969	7,341	7,478	1,760
1970	4,318	14,730	1,782
1971	3,872	66,933	5,466
1972	24,710	50,393	7,755
1973	38,595	45,983	9,900
1974	50,489	52,622	12,383
1975	45,187	32,087	9,951
1976[1]	213,552	215,128	51,619
1977[2]	42,631	66,879	12,088
Total	594,101	746,459	153,978

[1]Volume estimates based on individual tally of 59 percent of all spots detected. Excludes National Forests and Big Thicket National Preserve.

[2]Volume estimates based on individual tally of 67 percent of all spots detected. Excludes National Forests and Big Thicket National Preserve.

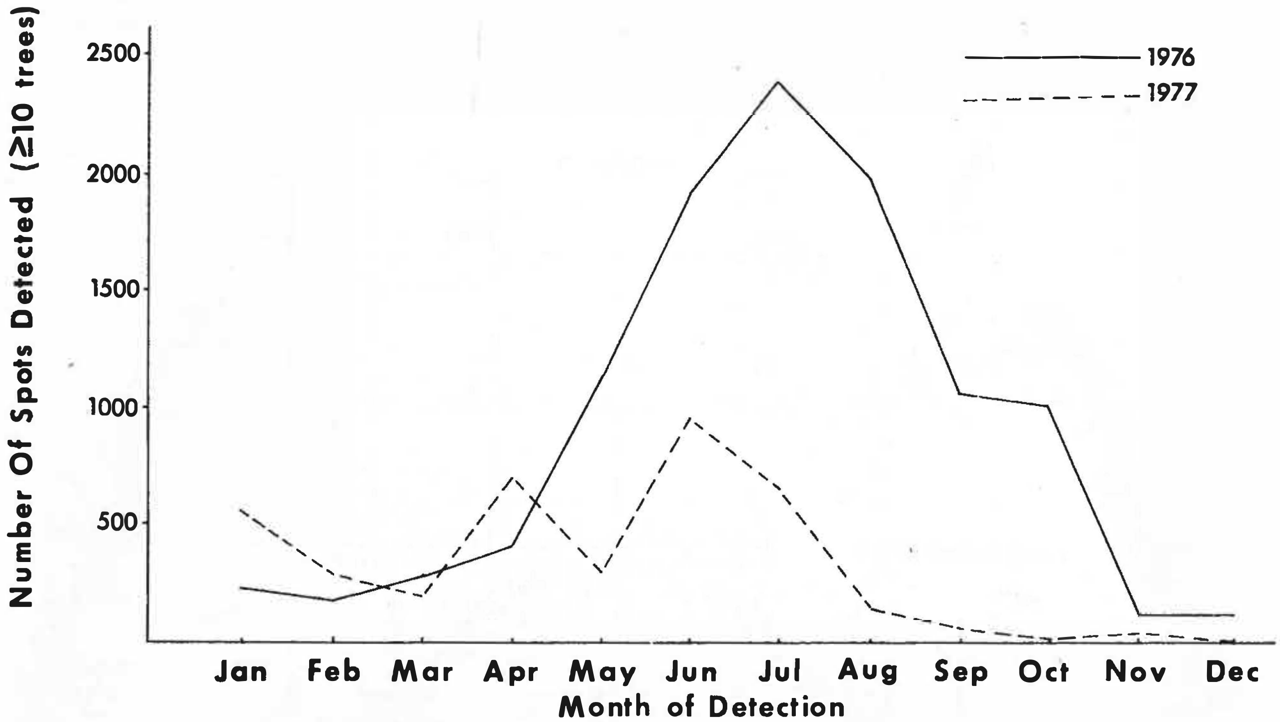


Figure 2. Southern pine beetle spots (≥ 10 trees) detected by month in East Texas during 1976 and 1977.

perienced during 1976 are discussed in a later section (Relationship of Beetle Activity and Weather Patterns, page 17).

Because of the severity of the 1976 outbreak, Governor Dolph Briscoe declared 34 counties of East Texas a disaster area on September 9, 1976, "due to a rapid spread of the pine tree beetle in the forested areas of the state." The beetle problem in Texas had made national news earlier with the release of an article in the *Wall Street Journal* on July 20, 1976. Thirty-eight counties (excluding Brazoria and Galveston counties, which are not within Texas Forest Service administrative boundaries) were reported infested in East Texas in 1976 (Fig. 3). By comparison, 25 and 28 counties reported SPB spots during 1974 and 1975, respectively. The ten most heavily infested counties during 1976, listed in decreasing order of magnitude, were Hardin, Montgomery, Liberty, Polk, Jasper, Tyler, Angelina, Cherokee, Newton and Harris. A complete listing of spots by county for 1976 and 1977 is given in Appendix II.

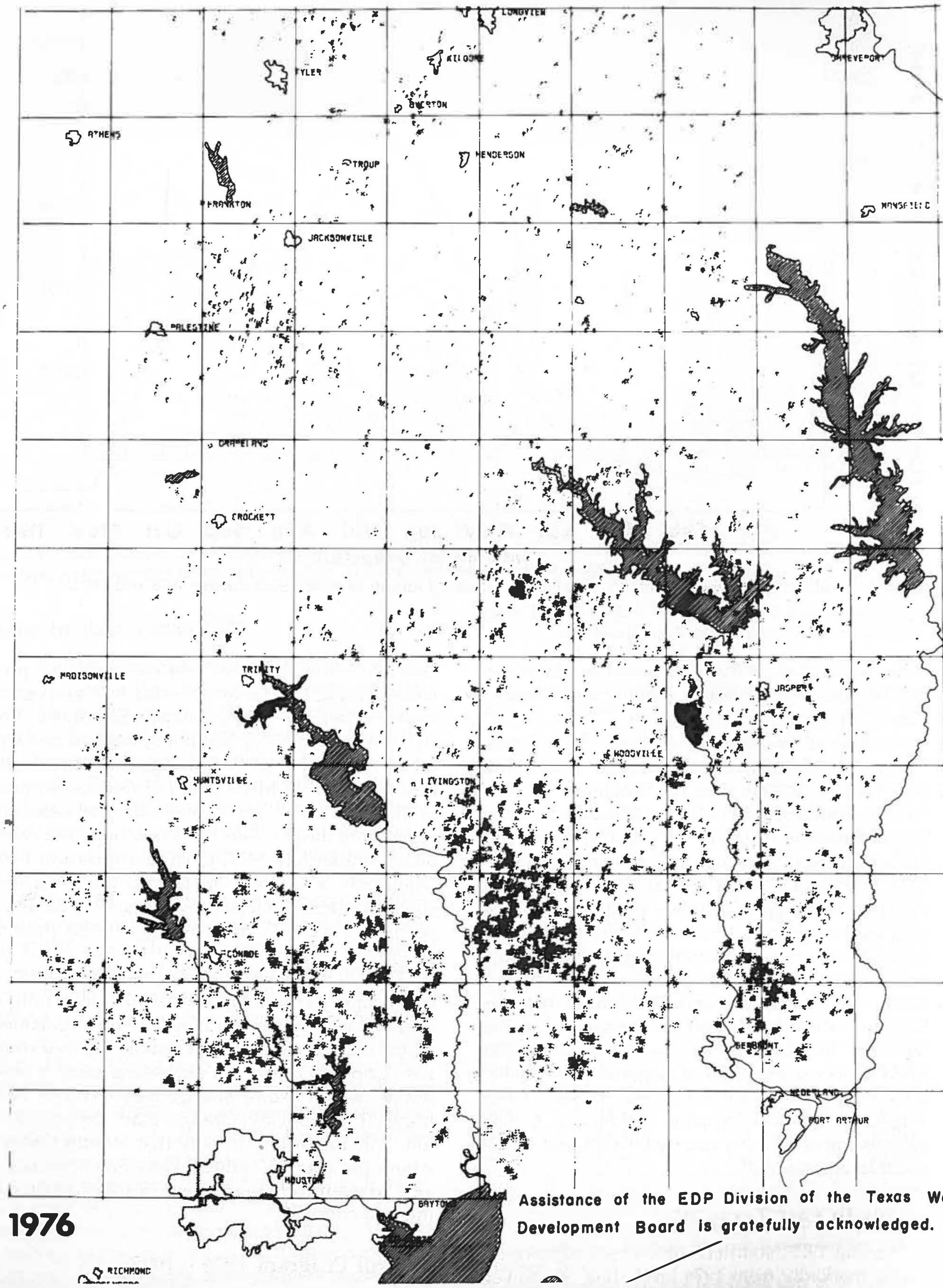
Status in East Texas 1977

During 1977, southern pine beetle activity declined markedly from 1976 levels (Fig. 4). Nevertheless, it was a moderate year for timber losses. A total of 4,333 spots was detected, amounting to an estimated loss of 12,087,600 cubic feet of pine timber (Table 1). The dollar value in stumpage of resource lost was approximately $3,000,000. The state-wide collapse of beetle populations perhaps is best reflected in the seasonal pattern of new spot detection (Fig. 2). Many of the spots detected prior to May 1977 were "carryovers" that had remained active from the previous year. Few new spots were detected after July 1977. In sharp contrast to 1976, when only 55 percent of the year's total of new spots had been detected by August 1, all but 7 percent of all 1977 spots were detected prior to August.

Thirty-five counties were infested in 1977 (3 less than in 1976). By the end of the year, only 15 counties had more than 5 active spots remaining on the records. The 10 most heavily infested counties during 1977, listed in decreasing order of magnitude, were Hardin, Montgomery, Liberty, Polk, Jasper, Tyler, Shelby, Orange, Harrison and Newton. It is interesting to note that Hardin County, where the current outbreak was first reported in 1957, remains consistently one of the most heavily infested counties.

Control Program 1976 - 1977

A complete list of timber losses and volume salvaged for East Texas in 1976 and 1977 is given



Assistance of the EDP Division of the Texas Water Development Board is gratefully acknowledged.

Figure 3. Computer plot of southern pine beetle infestations detected and controlled in East Texas during 1976. (See Appendix II for list of spots in northeastern counties not shown.)

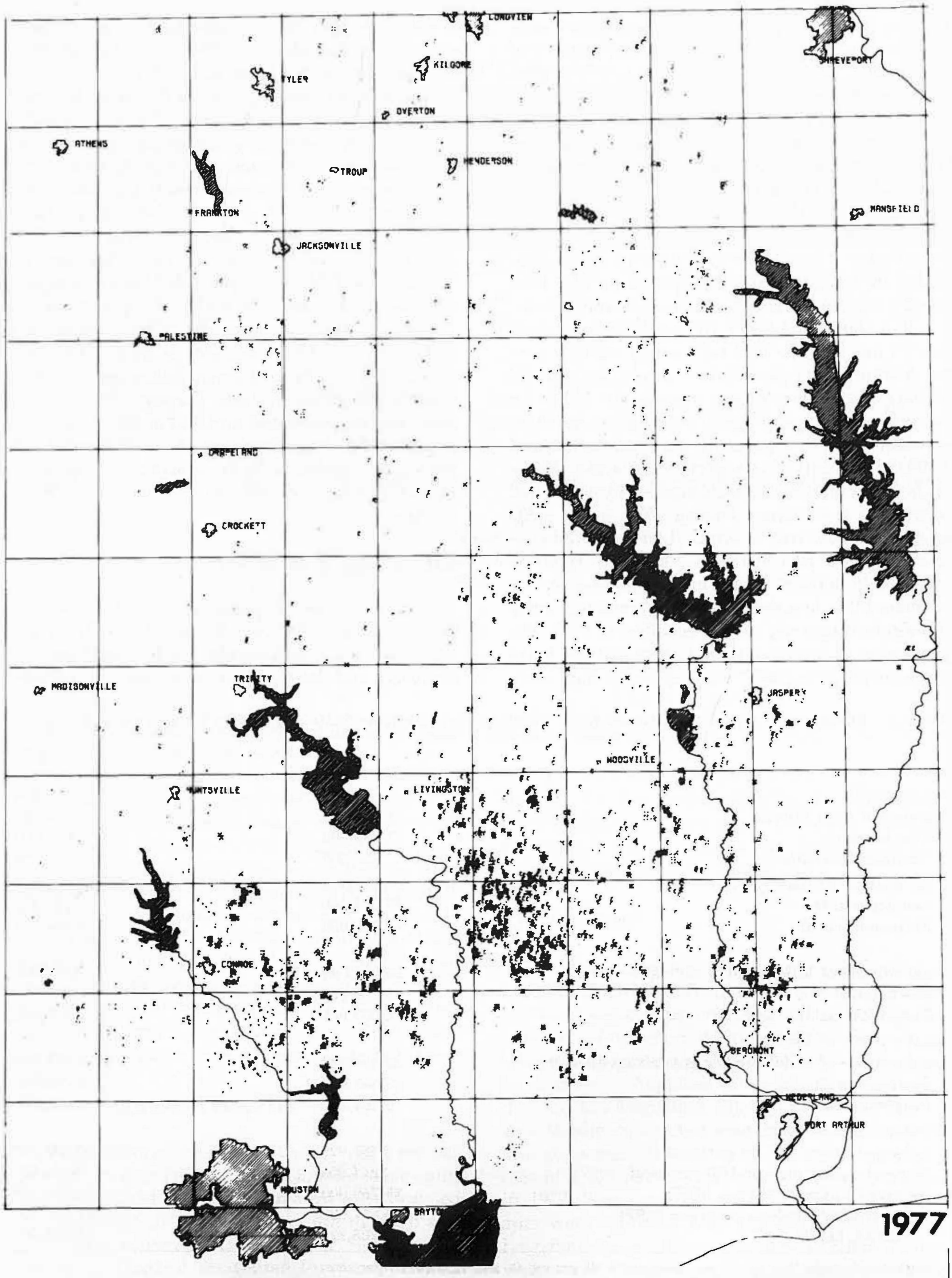


Figure 4. Computer plot of southern pine beetle infestations detected and controlled in East Texas during 1977. (See Appendix II for list of spots in northeastern counties not shown.)

in Table 2. In spite of excessive timber losses during 1976, approximately half of the total volume of beetle-killed timber was salvaged. In 1977, 60 percent was salvaged.

In a control program dedicated to minimizing timber losses, salvage and cut-and-leave continued to be the preferred control tactics during 1976 and 1977 (Table 3). Cut-and-leave was used more commonly than salvage as a direct control in Texas Forest Service Areas III and IV during 1977; nevertheless, much of the timber in spots controlled by cut-and-leave was picked up at a later date by salvage crews to reduce economic losses.

On a state-wide basis, the proportion of spots that go inactive (vacated by beetles) without control treatment has proven to be a reliable indicator of bark beetle population trends. In 1976, for example, 10,926 spots ($\geq$ 10 trees) were detected, of which 4,227 (39 percent) were controlled and 3,900 (36 percent) were reported as inactive. Many of the remaining 3,000 spots apparently continued active into the winter. During 1977, some 4,333 spots were detected, of which 1,954 received control action (45 percent) and 2,001 were reported inactive (46 percent) by the end of the year. It was estimated that less than 200 spots remained active throughout the state as of December 1, 1977. The proportion of large spots that went inactive without control during 1977 was atypically high compared to previous years (Table 4). This is a further reflection of the collapse of beetle populations that occurred during the latter half of 1977.

The average time lapse from detection to inactivity was 54.3 days in 1976 and 75.8 days in 1977. The difference between years reflects the fact that many large spots detected early in 1977 went inactive during the late summer months, unlike 1976. For all spots ground checked, the average time lapse from detection to ground check was 29.4 days in 1976 and 34.3 days in 1977. Averages of 58.3 days and 52.3 days prevailed between detection and control for 1976 and 1977, respectively.

On national forest lands in East Texas, an additional 193,400 cubic feet of pulpwood and 6,747,000 board feet of sawtimber were salvaged from beetle spots in 1976. During 1977, 371,926 cubic feet of pulpwood and 14,807,000 board feet of sawtimber were salvaged. An additional 2,522 trees were treated with the insecticide lindane to reduce beetle populations in 1977 at a cost of $4.07 per tree.

Other Bark Beetles

Bark beetle pests commonly found in association with SPB in the pine forests of East Texas include the black turpentine beetle (*Dendroctonus terebrans*), and three species of engraver or *Ips* bee-

Table 2. Summary of 1976 & 1977 Losses from Southern Pine Beetle on State and Private Lands in East Texas.[1]

	1976	1977
Acres of kill	41,300[2]	9,670[2]
Number of trees killed	3,091,000	724,300
Merchantable	2,734,000	627,000
Non-merchantable	357,000	97,300
Total volume killed-cu. ft.	51,619,000	12,087,600
Sawlogs-cu. ft.	35,592,000	7,105,100
Pulpwood-cu. ft.	16,027,000	4,982,500
Total volume of killed timber salvaged-cu. ft.	26,053,000	7,295,800
Sawlogs-cu. ft.	19,230,000	4,384,700
Pulpwood-cu. ft.	6,823,000	2,911,100
Total volume of killed		
Total volume of killed timber not salvaged-cu. ft.	25,566,000	4,791,900
Sawlogs-cu. ft.	16,362,000	2,720,500
Pulpwood-cu. ft.	9,204,000	2,071,400
Estimated dollars of resource lost		
Salvaged pulpwood ($5 per cord)	$457,920	$195,375
Non-salvaged pulpwood ($7 per cord)	$864,805	$194,630
Salvaged sawlogs ($50 per MBF)	$5,769,000	$1,315,410
Non-salvaged sawlogs ($100 per MBF)	$9,817,200	$1,632,300
TOTAL LOSS	$16,908,925	$3,337,715

Conversion factors: 74.5 cu. ft. per cord, and 6 BF per cu. ft. and 1250 cu. ft. per acre.

[1]Does not include losses on federal lands in East Texas.

[2]Acreage calculated by assuming an average of 1250 cu. ft. per acre (7500 BF). The total volume killed was divided by 1250.

Table 3. Summary of Southern Pine Beetle Control Efforts on State and Private Lands in East Texas — 1976 & 1977.

Year	Type of control	Texas Forest Service Area I	II	III	IV	V	Total	Percent of total controls
1976	Salvage	192	182	564	1179	160	2277	54
	Cut-and-Leave	44	14	494	1134	80	1766	42
	Cut-and-Top	2	0	1	57	3	63	1
	Insecticide (BHC)	0	0	0	2	0	2	< 1
	Combination	1	1	44	71	2	119	3
	Total control	239	197	1103	2443	245	4227	100
	Total inactive	212	104	950	1729	905	3900	
1977	Salvage	115	43	81	431	79	749	38
	Cut-and-Leave	19	2	103	955	30	1109	57
	Cut-and-Top	1	0	1	38	0	40	2
	Insecticide (BHC)	0	0	0	2	0	2	< 1
	Combination	0	1	2	51	0	54	3
	Total control	135	46	187	1477	109	1954	100
	Total inactive	130	53	469	842	507	2001	

Table 4. Comparison of Southern Pine Beetle Spot Inactivity and Control by Spot Size for 1976 and 1977 in East Texas.

Spot size interval[1]	1976 Percent inactive	1976 Percent controlled	1976 Percent remaining active[2]	1977 Percent inactive	1977 Percent controlled	1977 Percent remaining active[2]
< 11	52	36	12	61	36	3
11-25	42	38	20	52	42	6
26-50	33	41	26	49	46	5
51-100	29	41	30	49	48	3
> 100	16	48	36	47	49	4

[1]Number of active trees as estimated from air (inactive spots) or ground (controlled spots).
[2]All spots not reported inactive or controlled.

tles, *I. calligraphus*, *I. grandicollis* and *I. avulsus*. A marked increase in *Ips* and black turpentine beetle (BTB) activity was observed throughout East Texas during the late summer months of 1977 as commonly occurs when SPB populations decline. Black turpentine beetle and *Ips* activity was reported as unusually high in Walker, San Jacinto and Montgomery counties during both 1976 and 1977. An estimated 1,000 trees were reported killed by *Ips* in Fayette and Bastrop counties during 1977. The recommended control for both *Ips* and BTB in commercial forests is prompt salvage of infested trees.

Reproduction Weevils

Reproduction weevils are usually not a serious problem in East Texas but occasionally cause damage in localized areas. The greatest losses caused by this insect to pine seedlings during 1976 and 1977 were reported in Polk, Tyler and Newton counties. Control strategies for reproduction weevils in Texas consist of chemical treatment of seedlings or a delay in replanting of one growing season. If a tract was logged in the summer, it should not be replanted until the second winter. If the area was logged in the winter, it could safely be replanted the following winter.

Defoliators

The most common defoliator of forest trees in East Texas during 1976 and 1977 was the town ant or Texas leaf-cutting ant (*Atta texana*). Other defoliators were reported from time to time. Texas leaf-cutting ants caused heavy losses to pine regeneration in Angelina, Cherokee, Rusk, Nacogdoches, San Augustine, Shelby, Houston, Newton and Hardin counties during both 1976 and 1977. The gross area affected was estimated to be in excess of 4,000 acres in 1976 and nearly 10,000 acres in 1977. Ten acres of defoliation by leaf-cutting ants were reported from Bastrop County in the Lost Pines area. A less common defoliator, pine web worm (*Tetralopha robustella*), was reported to have stripped 75 acres of pine in Hardin County and 200 acres in Red River County in 1977. No

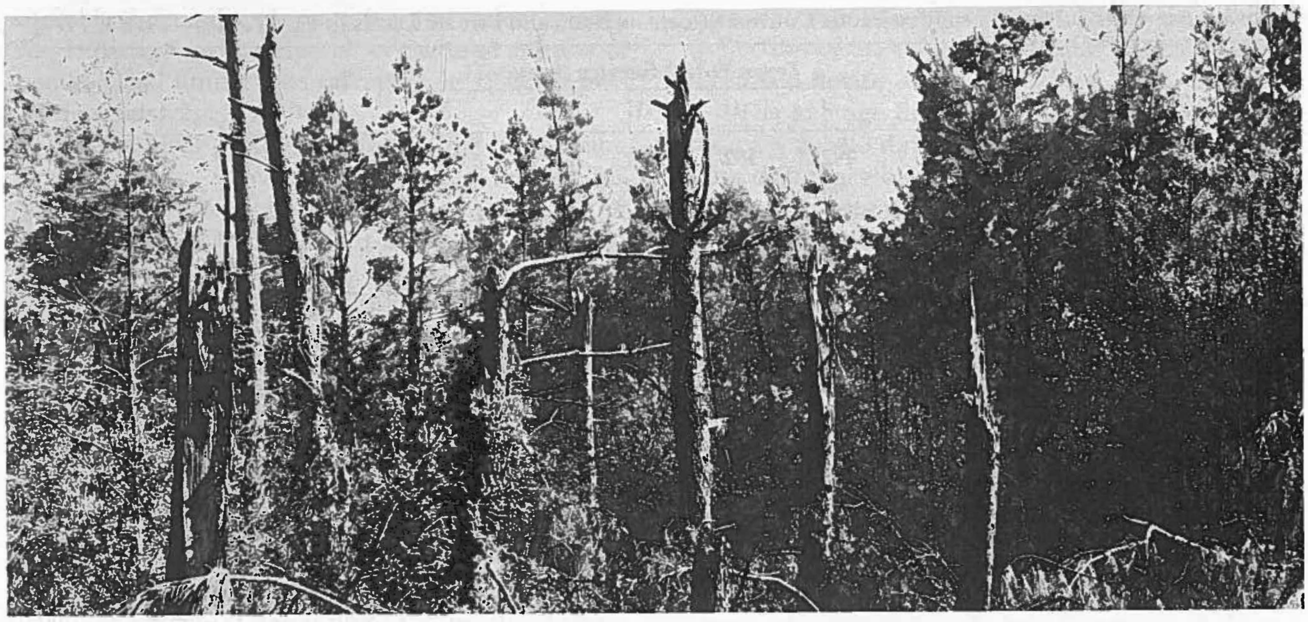


Figure 5. Damage to pines caused by tornado-force winds near Pennington, Texas, in March 1976.

reports of sawfly damage in East Texas were received for 1976 or 1977.

Tip Moths

Pine tip moths (*Rhyacionia* spp.) seldom kill trees, but can cause serious growth losses and poor tree form due to repeated attacks on terminal and lateral buds. Some 200 acres were reported infested in Liberty County in 1976 with Marion, Harrison, Gregg and Cass counties also reporting light activity. Increasing tip moth activity was reported in Newton and Cass counties while light activity occurred in Panola, Marion, Harrison and Gregg counties during 1977. Tip moths also have caused increasing concern as pests in Christmas tree plantations located throughout East Texas. Research is in progress to develop insecticide treatments to control tip moths in such high-value plantations.

Forest Diseases

Fusiform rust (*Cronartium fusiforme*), a common infectious disease of commercial pine forests, was observed over an estimated 3,000 acres of Bowie County and 25 acres of Newton County in 1977. No reports of this disease were received for 1976. Pine needle cast, caused principally by the fungus *Hypoderma lethale*, was reported to be abundant in Hardin, Liberty, Chambers and Jefferson counties during 1976 and 1977. About 500 acres of needle cast were reported for both years in Bastrop County. This disease usually does not kill the trees but often creates concern because of the unhealthy appearance of infected foliage. Some reduction in growth may occur due to loss of photosynthetic materials in the crown.

Weather Damage

Adverse weather conditions caused notable damage to forests in East Texas on at least two occasions in the spring of 1976. An early spring hailstorm near Corrigan (Polk County) devastated nearly 8,000 acres of forested land. The storm was so severe that it stripped bark, needles and leaves from the trees, killed birds, rabbits and other small animals and piled up hail two feet deep in some places. Timber damage was estimated in the millions of dollars by a timber industry representative. A large portion of the area was salvaged, so the timber was not totally wasted.

A tornado ripped through a strip of the Davy Crockett National Forest and private forest land near Pennington (Houston County) in March 1976 causing localized heavy damage. Even though the tornado damage was not widespread, it was quite spectacular (Fig. 5).

Recent Activities and Developments

The Forest Pest Control Section is actively involved in applied research concerning two major pest problems: southern pine beetle and seed orchard insects. A number of research projects have recently been completed and the results published while others remain in progress. A summary of the more pertinent findings and the literature citations are presented below. Copies of published articles are available from the Pest Control Section upon request.

Forest Industry Attitudes Toward SPB Control

In October 1976, the Pest Control Section distributed a questionnaire to representatives of major forest industries in East Texas who are directly involved with southern pine beetle control. The opinions of 30 line and staff members from 10 companies concerning suggested alternatives for SPB direct suppression or long range prevention were documented. The current approach to direct control by means of salvage or cut-and-leave was unanimously considered a practical approach and is currently being used by all companies polled. Among new tactics suggested for SPB control, thinning, prescribed burning and aerial application of pheromones, systemics or herbicides to disrupt spot expansion appeared most compatible to large company management plans. In contrast, most representatives were opposed to solutions that involved changing tree species or age composition of pine stands or to taking no direct action to control SPB infestations.

Billings, R. F. 1977. Forest industry attitudes toward southern pine beetle control. Texas Forest Service Publication 114:6 pp.

Habits of SPB Vary with Seasons

This illustrated circular, written in nontechnical terms, describes the infestation patterns and attack behavior of the southern pine beetle and how these habits vary from season to season. For landowners, an understanding of these seasonal changes in behavior is helpful in conducting programs of direct control and prevention.

Texas Forest Service. 1977. Southern pine beetle: seasonal habits in East Texas forests. Circular 228: 6 pp.

Size and Fat Content of SPB Change with Seasons

This study showed that the average fat content and size of newly emerged southern pine beetle adults varied with season in East Texas. Fat content (a measure of fuel available for long distance flight) was highest in beetles emerging during the spring and fall and lowest for beetles emerging during the hot summer months. Beetles were smallest during the months of July, August and September. Females, in general, were larger and had higher fat contents than males at all seasons. Implications of these findings in relation to bark beetle dispersal and seasonal behavior are discussed.

Hedden, Roy L. and Ronald F. Billings. 1977. Seasonal variations in fat content and size of the southern pine beetle in East Texas. Annals of the Entomological Society of America 70: 876-880.

SPB Brood Development in Relation to Tree Fade

Loblolly pines infested by southern pine beetle during each of twelve consecutive months were monitored to document seasonal relationships between SPB brood development and visual patterns of foliage discoloration. On the average, the foliage of trees infested during the winter months (November 1976 - January 1977) remained green 2 to 3 times longer than that of trees infested from March through September (Fig. 6), although there was considerable variation among individual trees during all seasons. In general, SPB broods emerged from winter-infested trees after foliage had begun to fall and from most summer-infested trees when the foliage occurred in the fading (yellow) color phase. Complete foliage loss occurred most rapidly for trees attacked in April (8.5 weeks after initial attack).

Billings, Ronald F. and Charles A. Kibbe. 1978. Seasonal relationships between southern pine beetle brood development and loblolly pine foliage color in East Texas. Southwestern Entomologist (In press).

How to Interpret SPB Activity from the Air

Annual patterns of new spot detection in East Texas, when interpreted with regard to foliage fade, support the conclusion that most new multiple-tree spots are initiated during the spring, with spot growth becoming the primary mode of beetle colonization during the summer months. Knowledge of these seasonal relationships was combined with other information from operational detection and control records (maintained by the Texas Forest Service) to formulate guidelines for improved detection and aerial evaluation procedures. Land managers faced with epidemic SPB populations in the Gulf Coast region can use these guidelines to reduce ground-check work loads

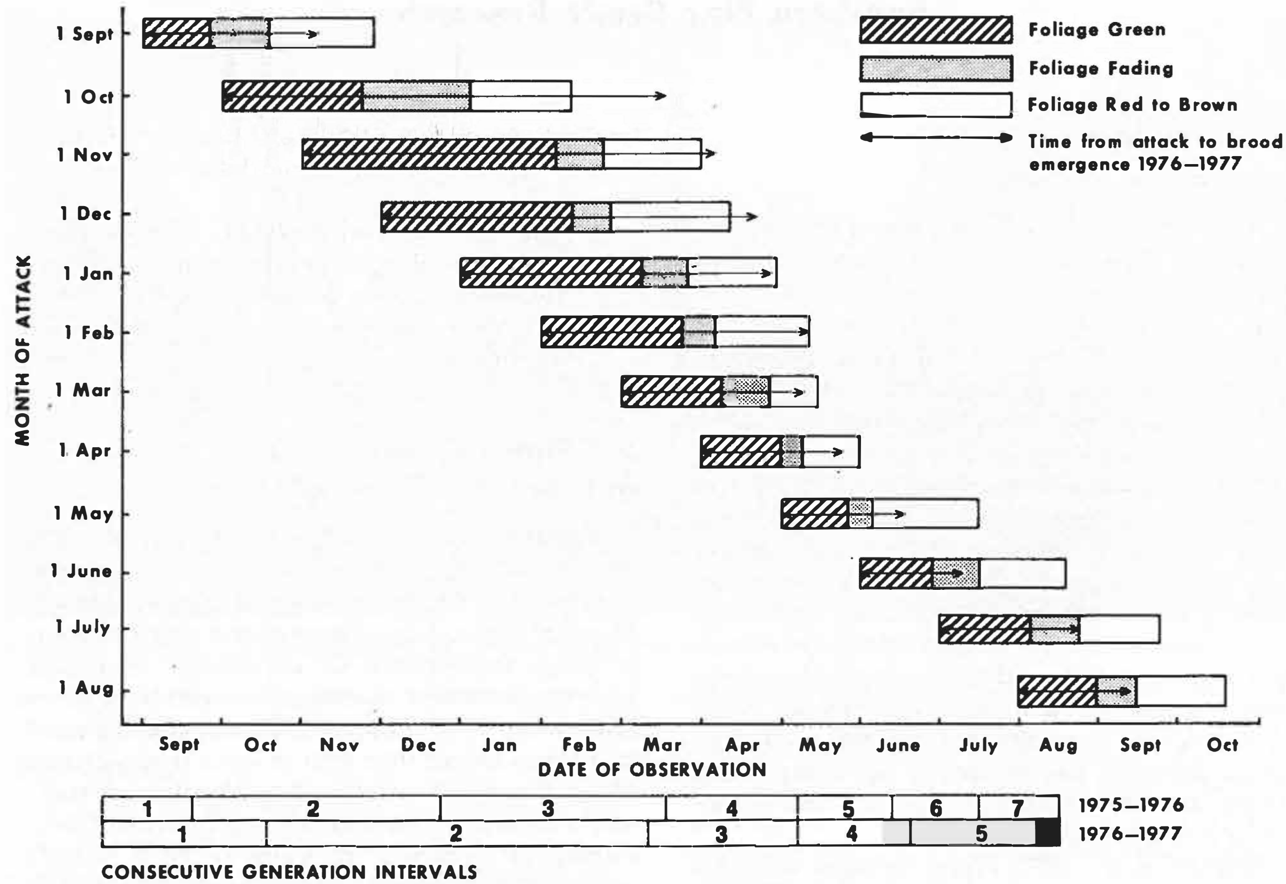


Figure 6. Seasonal relationships between southern pine beetle brood development and loblolly pine foliage fade for trees infested during the period September 1976 to August 1977. Approximate time intervals for consecutive generations of SPB during 1975-1976 compared to 1976-1977 also are shown.

and increase the efficiency of control operations.

Billings, Ronald F. 1978. Detecting and aerially evaluating southern pine beetle outbreaks — operational guides. Southern Journal Applied Forestry (In press).

Factors Affecting SPB Spot Growth and Inactivity

Over a 3-year period, the Pest Control Section monitored the expansion of selected southern pine beetle spots during the summer. The influence of site and stand factors on the duration and rate of expansion of 62 spots, ranging in size from 6 to 285 active trees, was determined. Two critical levels of beetle activity limiting summer spot growth were identified. In small spots with less than 10 brood trees, further expansion seldom occurred after detection due to insufficient beetle numbers. In large spots (more than 80 active trees), an upper threshold was attained when rates of attack exceeded approximately 2.5 trees infested per day. At this level of beetle activity, spots continued to expand rapidly even in sparse stands that normally would not support beetle activity. Between this upper and lower threshold, however, the rate and duration of expansion was highly dependent on prevailing stand conditions; growth of spots was most rapid and persistent in dense stands (Fig. 7). Average rates of spot growth, however, varied considerably from year to year (Fig. 8), a reflection of changes in statewide beetle population levels. The importance of these findings for direct and indirect control of the beetle is discussed.

Hedden, Roy L. and Ronald F. Billings. 1978. Southern pine beetle: factors influencing growth and decline of summer infestations in East Texas. (Manuscript submitted to Forest Science).

SPB Outbreak Related to Changes in Forest Conditions

Forest inventory records show that the overall structure of commercial forests in East Texas has

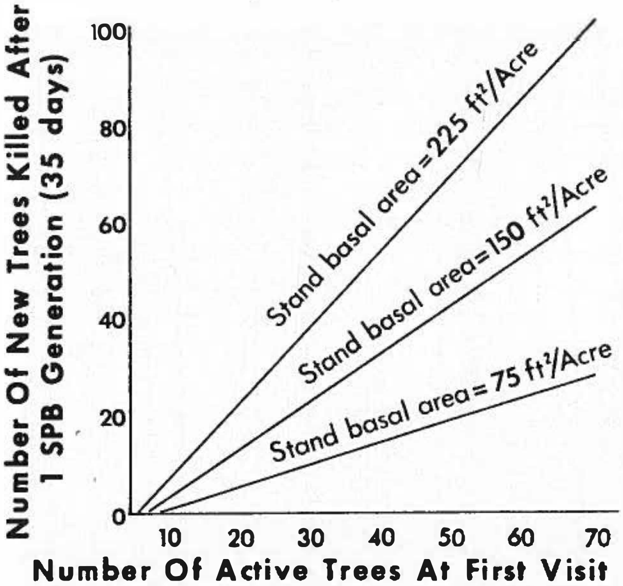


Figure 7. Influence of stand basal area (pine + hardwood) and the number of active trees at first visit on the subsequent number of new trees killed due to spot growth during one SPB generation interval (35 days). Data collected in summer of 1975 in East Texas. Vertical axis also represents number of active trees remaining in each spot 35 days after first visit.

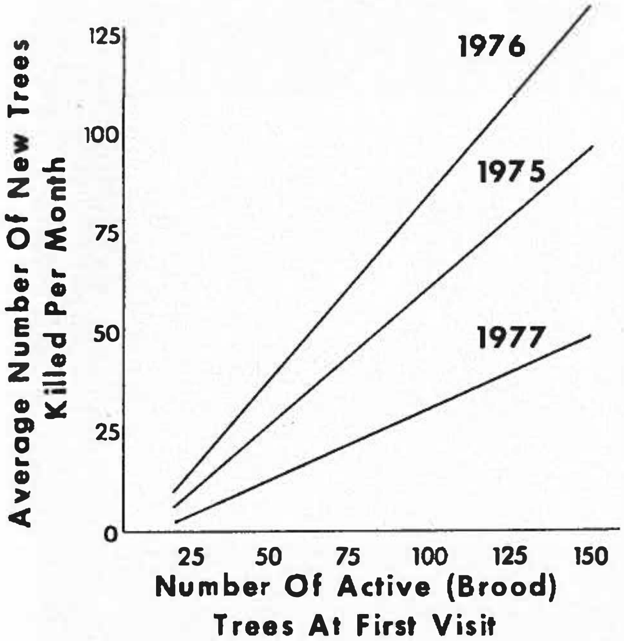


Figure 8. Annual differences in mean rates of spot growth for spots monitored during the summer months of 1975-1977. Mean stand basal area for sample spots within each year were 152 ft²/acre in 1975, 129 ft²/acre in 1976 and 166 ft²/acre in 1977.

changed markedly in the past 20 years. Since 1955 the amount of land in commercial forests has declined by 6 percent while the volume of timber per acre, particularly pine sawtimber, has almost doubled (Fig. 9). During this same interval, the southern pine beetle problem has grown increasingly worse (Fig. 1). It is suggested that increasing numbers of high-density pine stands susceptible to beetle attack have become available for infestation, resulting in a greater number of spots developing

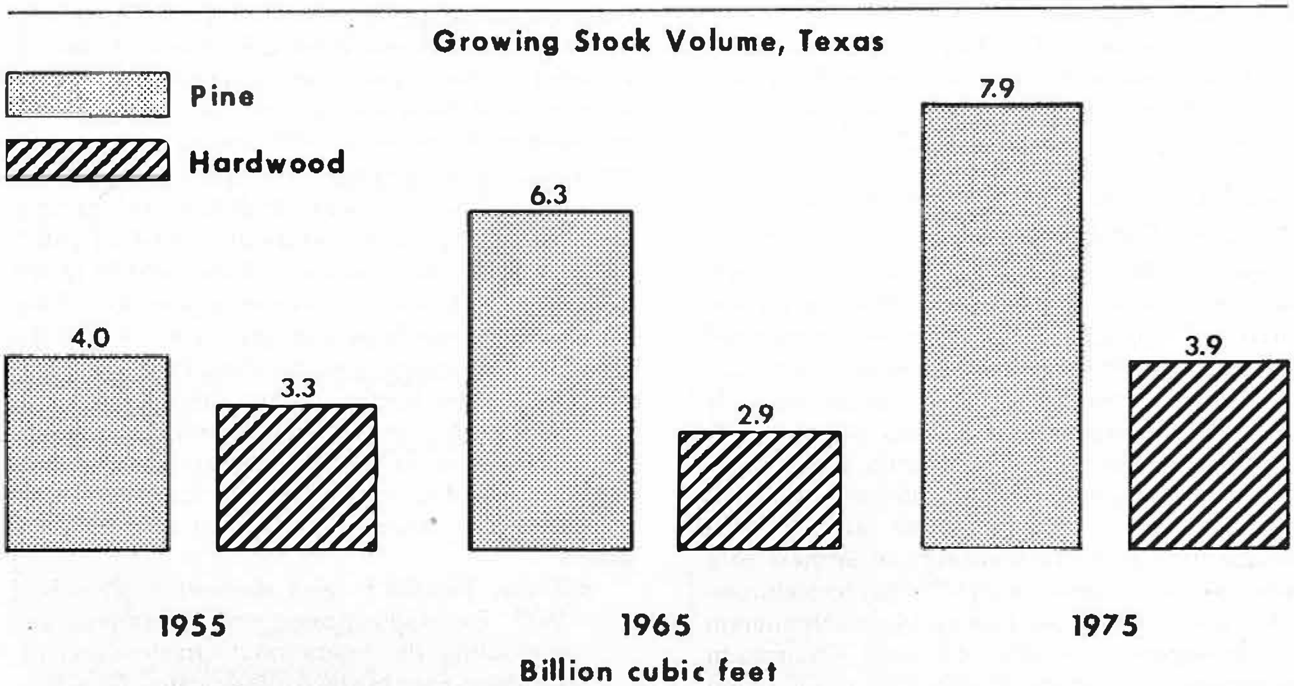


Figure 9. Changes in the volume of pine and hardwood growing stock in East Texas 1955-1975.

Figure 10. Densely stocked, unmanaged pine stands (left photo) have been shown to suffer more losses from both the occurrence and persistance of southern pine beetle infestations than do rapidly growing, thinned pine stands such as those shown at right.

each year. This trend is expected to continue unless more intensive forest management practices are adopted throughout East Texas to reduce the preponderance of over-dense pine stands favored by the beetle (Fig. 10).

Roy L. Hedden. 1978. The need for intensive forest management to reduce southern pine beetle activity in East Texas. Southern Journal Applied Forestry 2: 19-22.

Does Direct Control of SPB Increase New Spot Proliferation?

A study, funded in part by the U.S. Department of Agriculture's Southern Pine Beetle Research and Applications Program, was conducted by the Pest Control Section to evaluate the operational effectiveness of various control methods now in use throughout East Texas (salvage, cut-and-leave, cut-and-top, no control). Using computerized state-wide detection and control records from East Texas for the period January 1974 through June 1976, an inventory of all new SPB spots reported in proximity (1/2 mile) to each controlled spot was compiled for an 18-month interval that encompassed the date of control. Changes in the expected frequency of new spot proliferation following control action was used as the basis for measuring the effectiveness of various control methods applied at different seasons. Results for 1974 treatments (Fig. 11) showed that numbers of new spots detected about both cut-and-leave and salvaged spots were lower than those which occurred about active, uncontrolled spots. Treatment by either method was most effective, in terms of reduced proliferation, when applied during the summer and least effective when applied after September. Analysis of 1975 operational records confirmed these findings. The frequency of new spot proliferation was greatest in mixed sawtimber-pulpwood stands and least in pure pulpwood stands, regardless of the control tactic used. In conclusion, no evidence was found to support the contention that direct control by cut-and-leave or salvage is aggravating the pest problem by scattering beetles into uninfested areas. On the contrary, the inability to control all summer infestations prior to beetle dispersal in the fall appears to be a more important factor hampering the long-term effectiveness of current control programs.

Billings, Ronald F. and Herbert A. Pase III. 1977. Developing improved techniques for evaluating the operational effectiveness of southern pine beetle control tactics. Final Report to the Expanded Southern Pine Beetle Program. 75 pp.

Why Control SPB Spots?

Recent findings from various Pest Control Section research studies, together with evidence from state-wide SPB operational records, were summarized in a one-page fact sheet to convince landowners of the need for direct suppression of active beetle infestations. Direct control of SPB infestations as soon as possible after detection is particularly important in the summer to minimize losses from spot growth and eventual new spot proliferation.

Texas Forest Service. 1977. Fact Sheet: Control of SPB Spots. Pest Control Section. 1 pp.

Field Bioassays of Aggregation Pheromones

Under the direction of Dr. J. P. Vité, visiting professor from Freiburg University in Germany, the Pest Control Section participated in field tests to confirm the attractiveness of recently developed synthetic pheromones for species of *Ips* beetles and ambrosia beetles. These insects are common associates of the southern pine beetle in East Texas. Results are reported in the noted technical publications:

Hedden, Roy L., J. P. Vité and Kenji Mori. 1976. Synergistic effect of a pheromone and a kairomone on host selection and colonization by *Ips avulsus*. Nature 261: 696-697.

Renwick, J. A. A., J. P. Vité and R. F. Billings. 1977. Aggregation pheromones in the ambrosia beetle *Platypus flavicornus*. Naturwissenschaften 64, S. 226.

J. P. Vité, G. Ohloff and R. F. Billings. 1978. Pheromonal chirality and integrity of aggregation response in southern species of the bark beetle *Ips*. Nature (in press) 2 pp.

Analysis of Operational Records

Detection, ground-check and control records for all multiple-tree spots on state and private lands in East Texas have been maintained in computerized files since initiation of the Texas Forest Service Operations Informational System in 1973. During the period 1973 to 1978, southern pine beetle populations in East Texas increased to unprecedented levels (1976), then declined dramatically to current low levels. The 5-year data bank is being analyzed to reveal important seasonal and annual relationships that may help in forecasting future outbreaks. These historical records are valuable as a source of information to document localities and stand conditions most prone to beetle attack. Through computerized records, areas that suffered repeated beetle problems in the past can be readily identified and given priority in silvicultural control programs to reduce the magnitude of future losses.

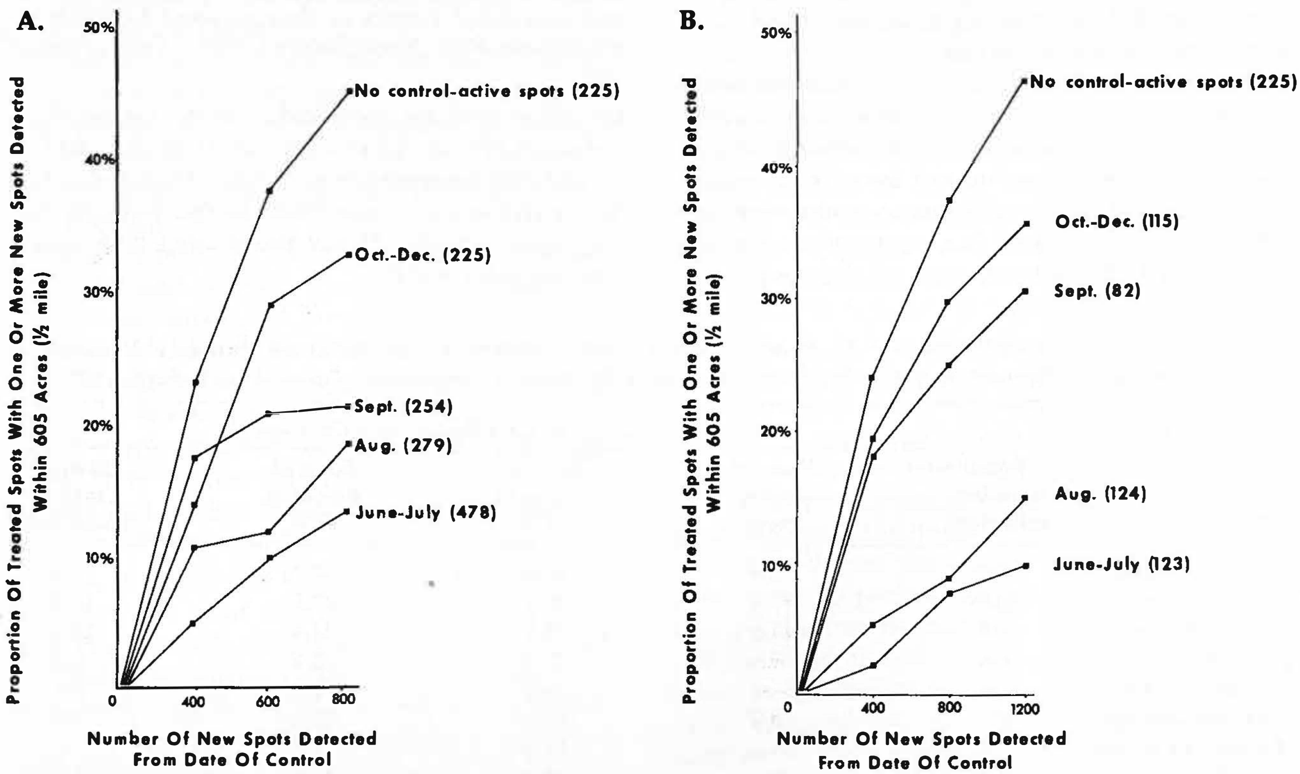


Figure 11. Level of new spot proliferation detected in proximity to spots controlled by salvage (A) and cut-and-leave (B) applied at different seasons as compared to active, uncontrolled spots.

Monitoring Beetle Populations with Flight Traps

During August and September 1977, simple and inexpensive barrier traps were designed for capturing flying bark beetles and their natural enemies. Three different sizes of traps were tested in the field by baiting each trap with synthetic bark beetle pheromones (Fig. 12). Preliminary results showed that traps with 50 × 50 cm polyethylene sheet panels were equally efficient for trapping beetles as traps with barriers 100 and 150 cm tall.

In a subsequent experiment, the aerial distribution of in-flight southern pine beetle and associated insects was monitored at distinct locations throughout an active SPB spot in Nacogdoches County. Flight traps with 50 × 50 cm barrier panels were located (1) at the active head of the spot, (2) in an uninfested stand 50 meters in front of the active head, (3) in vicinity of trees from which SPB were emerging, and (4) in the inactive portion of the spot.

Three traps were located in each locality; each trap was baited with the pheromones frontalure (for SPB), ipsdienol and ipsenol (for *Ips*). Insects in the water-filled collection trays were collected every 3 days for a 9 day period. Results (Table 5) indicated that the traps were useful for trapping a variety of scolytid beetles and clerid predators. Also, the spatial distribution of catches varied, depending on the insect species.

The southern pine beetle, black turpentine beetle (*Dendroctonus terebrans*) and the clerid (*Thanasimus dubius*) were most abundant in traps located within the active head of the spot. *Ips avulsus* and a species of *Pityophthorus* were abundant in both the active head and in vicinity of trees with emerging SPB. The other insects, including *Ips calligraphus* and *Ips grandicollis*, were captured in comparable numbers at all trap locations. Additional experiments are being conducted to test the usefulness of water-filled barrier traps as survey tools for periodically monitoring bark beetle and predator levels.

Figure 12. Barrier traps designed to catch bark beetles and associated insects as they respond to synthetic pheromone baits. Nacogdoches County, Texas, August 1977.

Table 5. Numbers of Bark Beetles and Associated Insects Caught in Pheromone-Baited Traps Situated at Various Locations Throughout an Active Southern Pine Beetle Spot Near Nacogdoches, Texas, Aug. to Sept. 1977.

Species	Total number collected[1]	Percentage of total caught in each zone: Zone of inactive trees	Zone of emerging SPB	Zone of attacking SPB	50 m in front of attack zone
D. frontalis (SPB)	553	0.9	18.6	80.1	0.4
Ips calligraphus	218	17.4	35.3	27.5	19.7
Ips grandicollis	162	21.0	30.2	20.4	28.4
Ips avulsus	136	4.4	47.0	42.6	5.9
D. terebrans (BTB)	19	----	26.3	73.7	----
Pityophthorus spp.	319	8.2	47.3	43.6	0.9
Thanasimus dubius	44	4.5	15.9	79.5	----
Cerambycidae	59	28.8	25.4	32.2	13.6

[1]Total from three identical traps per zone, each baited with frontalure, ipsenol, ipsdiensol.

Relationship of Beetle Activity and Weather Patterns

Populations of the southern pine beetle in East Texas increased steadily from relatively low levels in 1970 to unprecedented outbreak proportions during 1976. Beetle activity since 1976 declined drastically to the apparently low levels that now prevail. Similar population buildups and corresponding declines were experienced in several previous periods during the past 20 years (Fig.1), although pre-1976 outbreaks were much less severe. It seems worthwhile to discuss some of the more obvious underlying factors associated with the 1976 outbreak and subsequent decline, even though conclusive evidence for direct cause-and-effect relationships often are lacking.

As documented in a recent article by Hedden[1], shifting stand conditions throughout East Texas (particularly increases in average tree size and basal area per acre, as well as decreases in the hardwood component of stands) appear to have contributed to the long-term increase in SPB populations experienced during the past 20 years. A beetle spot is more likely to occur in overly dense, pure pine stands and, once established, such spots tend to grow larger and persist longer than those in sparse stands. In turn, dense stands susceptible to beetle attack are more abundant now than ever before in recent history.

Other factors, however, are believed responsible for short-term fluctuations in beetle populations, as area-wide stand conditions do not change drastically from one year to the next. Weather, with its direct and indirect effects on the beetle-host tree-natural enemy system, appears to have contributed most to beetle population changes during the past several years. SPB brood development is most rapid and survival is greatest in the temperature range of 70-85°F. Below 60°F, neither adult emergence nor flight takes place and below 40°F brood development is curtailed. Similar detrimental effects begin to occur when temperatures exceed 90°F; beetles mature more slowly, brood quantity and quality (size and fat content) are reduced and flight capabilities are diminished.

From 1974 to 1976, winters in East Texas were notably milder than normal, and summers were cooler than normal — in other words, the extremes of winter and summer temperatures were buffered. Such conditions allowed beetles to remain active throughout the year resulting in seven or more generations per year (Fig. 6), with high survival in each generation. Above average rainfall (1973-1975) and flooded ground conditions, particularly in southeastern countries, placed pine stands under severe stress and at the same time prevented access to many infestations by control crews. The result was a rapid and continuous beetle population buildup that reached a climax during 1976.

The collapse of SPB populations in 1977 again is logically attributable to weather conditions — weather that was markedly different than that experienced from 1974 to 1976. For example, mean monthly temperatures dropped more than 8° F below normal in October 1976 and remained atypically low throughout the winter months. Spot growth was brought to a virtual standstill during the winter of 1976-77, unlike the previous winter when certain spots were observed to double in size from November through January. Prolonged developmental rates (Fig. 6) during the winter of 1977 also exposed beetles to greater predation by woodpeckers and more effective salvage control programs.

The summer of 1977, in turn, was exceptionally warm compared to recent years. For example, maximum daily temperatures exceeded 95°F during 31 days in June, July and August 1977 in Lufkin, compared to only 7 days in 1976. The average time required to complete one SPB generation was increased to about 40 days during the summer months of 1977, compared to 30 days in 1976. Under these cold winter and hot summer conditions, we observed only about five beetle generations for the one-year period September 1976-September 1977 (Fig. 6). Concurrent with slower beetle development (or perhaps as a result of this), brood production and survival within trees appeared greatly reduced during the summer of 1977. An abundance of fungal activity caused by the bluestain fungus, *Ceratocystis minor*, was evident in the inner bark of infested trees. This fungus, which is transported by the beetle itself, usually aids beetle survival by reducing the moisture content to levels optimal for larval development. Presumably, the high summer temperatures during 1977 favored development of the fungus to the detriment of beetle larvae. It was common to find large areas of inner bark occupied by the fungus, with beetle larvae developing to maturity only in bark areas without high fungal infection (Fig. 13). Larvae, forced to feed in infected zones, constructed atypically long galleries and seldom completed development. This phenomenon, seldom observed during 1976, is known to reduce larval survival, and subsequent adult beetle population levels.

[1]Hedden, R. L., 1978. The need for intensive forest management to reduce southern pine beetle activity in East Texas. Southern J. Applied Forestry 2:19-22.

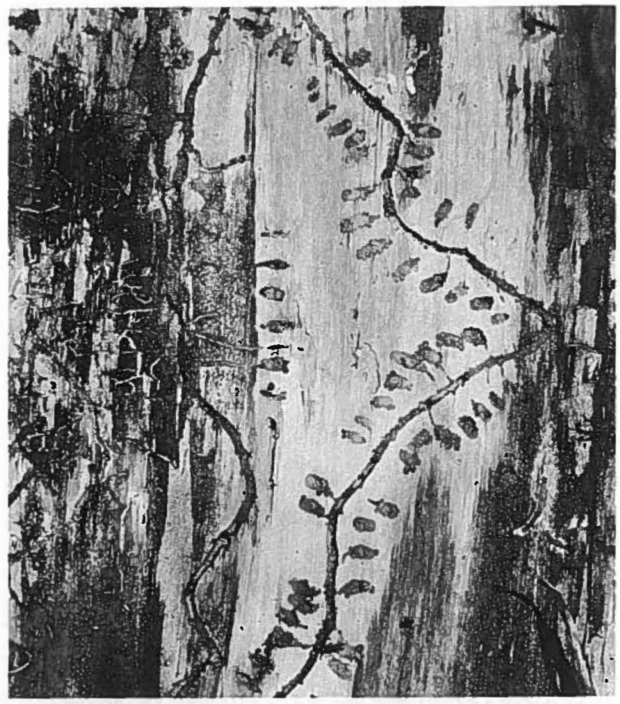


Figure 13. Gallery patterns produced by southern pine beetle in 1976 (A) and 1977 (B). Note black areas infected by the blue-stain fungus *Ceratocystes minor* in Figure B and the atypical, elongated galleries made by SPB larvae in these infected areas.

This is just one of many ways in which changes in weather may have profoundly influenced the balance between SPB and associated organisms, contributing to the population collapse.

No doubt the preceding observations have omitted many additional variables that were involved in beetle population fluctuations during 1976 and 1977. Nevertheless, prevailing weather conditions remain the most obvious cause of short-term beetle fluctuations. In fact, researchers at Stephen F. Austin State University, Nacogdoches, recently developed a model to predict the total number of infestations detected per year in East Texas that relies solely on weather variables (mean February temperature and rainfall patterns during the previous year).[2]

The SPB is likely to again increase to pest levels as soon as weather patterns shift in its favor. The extent of future timber losses to be suffered in the next outbreak will depend on a number of factors, including (1) the length of favorable weather intervals (2) the abundance of susceptible host type and (3) the effectiveness of direct suppression programs. With beetle populations at a low level, now would be the ideal time for landowners to begin forest management practices that will eliminate stand conditions known to invite beetle problems.

[2]Kroll, J. C. and H. C. Reeves, 1978. A simple predictive model for potential southern pine beetle activity in East Texas. Southern J. Applied Forestry 2:62-64.

Cone and Seed Insect Research

To meet increasing demands for high-quality pine seed for reforestation programs in East Texas, seed orchards have been established from parent trees genetically selected for outstanding characteristics of growth, form, fiber or drought hardiness. The utilization of genetically-improved seedlings is expected to increase wood production, decrease rotation time and provide a higher quality product. Investment in high-value seed orchards has brought about the need to identify mortality factors that affect seed yield within the orchard, including tree physiology, weather, insects and diseases. Insects, particularly coneworms, seedbugs and seedworms, are believed to be a major cause of seed and cone mortality in southern pine seed orchards. Accordingly, the Pest Control Section is involved in research to document the economic impact of various insect species in Texas Forest Service seed orchards. Our ultimate goal is to develop practical and economically feasible methods to minimize insect damage through the nearly two-year period of seed development from the flower stage to cone harvest.

Mortality of seed and cones can occur at any point during this long maturation process. Pine trees have male catkins which produce pollen and female cones which produce seed. The female flowers are first formed inside the buds during the summer. The following spring they emerge from

the bud-like scales at the tips of the new shoot growth. Each fertile scale of the female flower contains a pair of ovules which have the potential to develop into mature seed. Soon after the ovules are pollinated in early spring, visible development ceases for more than a full year. During this period the female flowers are called conelets.

The egg cell within each ovule is not fertilized until vegetative growth starts the second spring. At this time, the conelet grows rapidly, developing into a full-sized cone by early summer. Seeds within cones do not attain full maturity until late summer or early fall. At this season, mature cones are harvested, and the fully developed seeds are extracted.

Some insects, such as coneworms, feed on the interior portions of conelets and cones, usually causing mortality of the entire structure. Seedbugs cause damage by penetrating the cone scales of both conelets and cones with their piercing-sucking mouthparts and removing the contents of the developing ovules and fully developed seed. Ovules damaged by seedbugs cease to develop and often the entire conelet is aborted. Pollination failure and developmental problems may also cause ovule and conelet abortion.

Ovules damaged and aborted during the first or second year of development are small or flattened and are discarded during the extraction process leaving only the developed seed. The contents of developed seed can be examined with X-rays to analyze seed quality. Seedbug damaged seed may be either partially filled or practically empty. Empty seed, however, may result not only from seedbug feeding but also from lethal alleles and fungal infection.

Impact of Cone and Seed Insects at Magnolia Springs Seed Orchard

A three-year study to identify and quantify insect-caused losses of cones and seeds in a Texas Forest Service loblolly pine seed orchard near Magnolia Springs was completed in 1976. Sample cones from two consecutive cone crops in a high wood specific gravity loblolly orchard were monitored at monthly intervals from flower initiation through cone harvest. No insecticide treatments were applied in the orchard during this study. The fully developed seed were extracted by tapping the base of each cone with a block of wood to simulate commercial extraction processes. The remaining seeds were manually removed from each cone. All seed from both extractions were radiographed to determine the number of seedbug-damaged, empty and apparently sound seeds per cone, stratified and finally germinated.

The results are summarized in Table 6. Coneworms of the genus *Dioryctria* accounted for the majority of the identifiable insect-caused damage to cones, most of which occurred during the second year of cone development. However, unknown factors caused considerably more mortality than all insects combined. Most of this unknown mortality occurred during the conelet stage (first year of cone development).

An analysis of the cone, seed, extraction and germination efficiencies (or survival rates) is a con-

Table 6. Conelet and Cone Mortality and Seed Yields per Cone for 1975 and 1976 Sample Cones in High Wood Specific Gravity Loblolly Pine Seed Orchard, Magnolia Springs, Texas.[1]

Cone mortality and seed yields	1975 Sample cones	1976 Sample cones
Conelet and cone mortality		
Number of initial flowers sampled	925	1590
Coneworms (*Dioryctria* spp.)	11.7%	11.3%
All other insects	1.5%	5.9%
Unknown factors	22.2%	35.3%
Total mortality	35.4%	52.5%
Seed yields and quality		
Number of cones sampled	597	755
Total number of seeds/cone	97.6	53.2
Total number of full seeds/cone	64.5	28.2
Percent full seed	66.1%	53.0%
Percent seedbug damaged seed	10.0%	16.4%
Percent empty seed	23.0%	29.4%
Percent full seed extracted	77.7%	74.1%
Percent germination of full seed extracted	93.4%	98.6%

[1]1975 and 1976 figures derived from 10% sample of initial flowers on each of 30 ramets, representing 7 clones; both cone crops were sampled on the same trees; unnatural mortality such as dead trees and man-caused mortality were excluded from the sample.

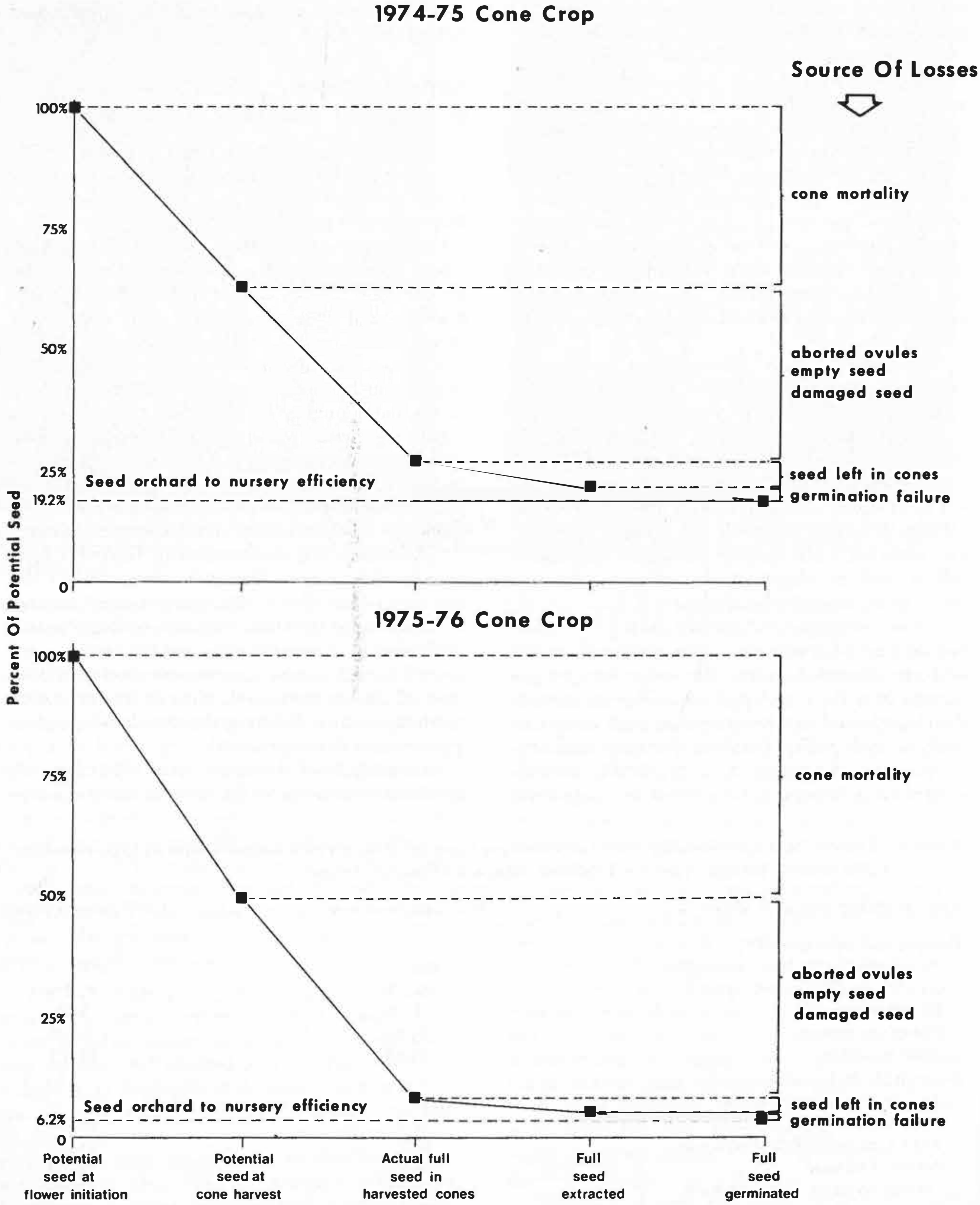


Figure 14. Survival of potential seed at various stages of cone and seed development for 1975 and 1976 cone crops in a loblolly pine seed orchard near Magnolia Springs, Texas.

venient method of visualizing losses from the flower stage through seed germination. These efficiencies can be defined as follows:

a. Cone efficiency (CE) =

$$\frac{\text{cones harvested}}{\text{initial flowers}}$$

b. Seed efficiency (SE) =

$$\frac{\text{total full seed}}{\text{seed potential (fertile cone scales} \times 2)}$$

c. Extraction efficiency (EE) =

$$\frac{\text{full seed extracted}}{\text{total full seed}}$$

d. Germination efficiency (GE) =

$$\frac{\text{extracted seed that germinated}}{\text{full seed extracted}}$$

e. Seed orchard to nursery efficiency (SO-NE)

$= CE \times SE \times EE \times GE$

The seed orchard to nursery efficiencies for the 1975 and 1976 cone crops were 19.2 percent and 6.2 percent, respectively (seed efficiency for the 1975 cone crop was based on 1976 seed potential data from the same trees). Losses during conelet, cone and seed development were severe, particularly for the 1976 cone crop, while extraction and germination losses were relatively small (Fig. 14).

Due to nutritional or physiological limitations, it is unlikely that a seed orchard to nursery efficiency of 100 percent could be achieved. However, efficiency analysis indicates at which stages of cone development attention needs to be focused to increase seed yields.

Caging Study (1975-1976) to Monitor Insect Losses

In order to better document cone and seed losses directly attributable to insects, selected cones from the 1975 crop were protected within cages (Fig. 15) during the second year of cone development (April through October 1975). In addition, flowers destined to become cones in 1976 were protected inside cages from April 1975 (after pollination) until cone harvest in October 1976. To allow statistical comparison of cone mortality and seed yields of cones protected in cages with that of cones exposed to natural insect populations, the cages were located on some of the same trees utilized in the impact study. The seeds from caged cones were extracted and analyzed by standard procedures described in the impact study. A paired comparison was used to test for significant differences in conelet and cone mortality, seed yields, seed quality, seed extraction and seed germination inside and outside cages (Table 7).

Mortality of 1975 cones protected only during the second year of development was significantly less than mortality among exposed cones. Conelet mortality for the 1976 cone crop was reduced inside cages, but cone mortality from November 1975 to harvest in October 1976 was nearly the same inside as outside cages.

The total number of seeds per cone was significantly increased in cones caged throughout development (1976 cone crop) but not in cones protected only during the second year of development (1975 cone crop). The number and percent of full seeds per cone were significantly increased in caged cones from both cone crops. With the exception of a few isolated seeds, possibly fed on through the netting, seedbug damage was excluded from the caged cones. Seed extraction was significantly increased for cones protected only during the second year of development but not for cones protected throughout development. Caging appeared to have no effect on the germination of full seed.

A large portion of the exposed conelets of the 1976 cone crop was aborted during the first year of

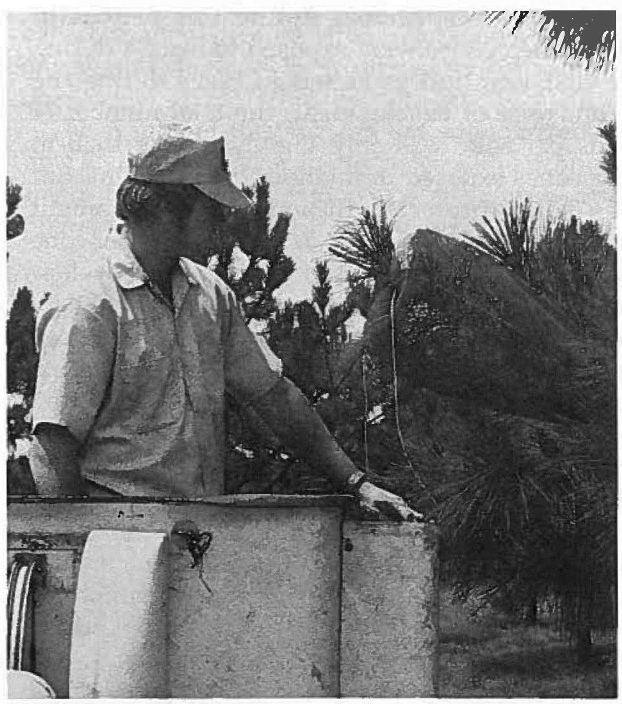


Figure 15. Screen cage used to protect conelets and cones from insect damage in loblolly pine seed orchard near Magnolia Springs, Texas.

Table 7. **Average Conelet and Cone Mortality per Tree and Average Seed Yields per Cone per Tree for 1975 and 1976 Cone Crops Protected in Cages Compared With Exposed Cones Harvested from Trees in a High Wood Specific Gravity Loblolly Seed Orchard, Magnolia Springs.**

Cone mortality and seed yields	1975 Cone crop		1976 Cone crop	
	Exposed	Caged during 1975 only	Exposed	Caged during 1975 and 1976
Percent conelet mortality of initial flowers (April-October 1975)	—	—	33.8%	7.6%[4]
Percent cone mortality of conelets surviving first year of development[1]	19.4%	7.2%[4]	26.0%	25.6% N.S.
Percent total mortality (April 1975-October 1976)	—	—	49.2%	28.4%[4]
Seed potential/cone[2]	157.0	157.0	156.2	156.2
Total seeds/cone	92.0	98.5 N.S.	53.8	117.5[4]
Full seeds/cone	52.3	70.0[4]	26.1	67.4[4]
Percent full seed	55.6%	72.2%[4]	47.9%	59.3%[3]
Percent seedbug damaged seed	13.8%	0.1%[4]	16.4%	0.0%[4]
Seed efficiency[2]	33.4%	46.1%[4]	17.0%	43.8%[4]
Percent full seed extracted	67.8%	85.0%[4]	61.6%	61.9% N.S.
Percent germination of extracted full seed	88.2%	90.6% N.S.	98.5%	97.6% N.S.
Seed orchard to nursery efficiency	—	—	5.1%	18.6%

[1]Percent cone mortality for 1975 cone crop over 7 month period (April 1975 to October 1975) and for 1976 cone crop over 11 month period (November 1975 to October 1976).

[2]1975 seed efficiency based on average seed potential for 1976 sample cones from cage study trees included in paired comparison; no significant difference found between a paired comparison of 1976 and 1977 average seed potential for seven trees ($t = .71$; $df = 6$).

[3]Paired comparison of means for caged and exposed cones significantly different at $P < 0.05$.

[4]Significantly different at $P < 0.01$.

development, while only a few of the conelets protected inside cages died during this period. In 1975, when cones were exposed to insects during the first year and protected in cages during the second year of development, the total number of seeds per cone was only slightly greater than in 1975 cones exposed throughout development. But 1976 cones protected throughout development produced more than twice as many seeds per cone as the 1976 cones exposed throughout development. Leaffooted pine seedbugs were excluded by cages and are known to cause conelet and seed abortion. In combination, these observations suggest that much of the unidentified cone and seed mortality which occurred outside cages was caused by seedbugs primarily during the first year of cone development.

When compared to cone and seed yields for the 1975 cone crop, certain results obtained for the 1976 cone crop provided evidence that prolonged caging *per se* may have caused detrimental effects on cone and seed production within cages. For example, contrary to expectations, cages did not reduce 1976 cone mortality nor produce increased extraction of full seed. The percent full seed in protected cones was less than the percent full seed plus seedbug-damaged seed in exposed cones. Despite possible detrimental caging effects, orchard to nursery efficiency for the 1976 cone crop was 18.6 percent for caged cones and 5.1 percent for exposed cones, giving more than a 3-fold increase in seed production inside cages which may be attributed largely to exclusion of seedbug damage. Seed orchard to nursery efficiency for protected cones may have been even greater if apparent detrimental effects of caging had not occurred.

Caging Study (1977) at Fastrill and Magnolia Springs

Similar caging studies were initiated in May 1977 in two Texas Forest Service loblolly pine seed orchards, one located near Magnolia Springs, and the other at the Fastrill Seed Orchard near Alto. Thirty-five ramets representing several clones were included in the Magnolia Springs study, and seven ramets all from the same clone were included in the Fastrill study. Preliminary results indicate that 11 percent and 12 percent of the fully developed seeds in exposed cones were damaged by seedbugs at Magnolia Springs and Fastrill, respectively. Conelet mortality from May through

November 1977, was 6 percent inside and 22 percent outside the cages in the Magnolia Springs seed orchard, and 4 percent inside and 91 percent outside the cages in the Fastrill seed orchard. This dramatic reduction in conelet mortality inside cages in the Fastrill seed orchard study may have been due to the exclusion of seedbugs. Radiographic analysis of seeds extracted from 1977 Fastrill cones revealed an average of 19.8 full seeds per exposed cone and 51.8 full seeds per protected cone. This large increase in number of full seeds per protected cone may also be due to the exclusion of seedbug feeding inside cages. The seed yields of the 1978 cones will be analyzed after cone harvest.

In an additional experiment, adults of the shieldback pine seedbug, *Tetyra bipunctata,* were introduced into 14 cages at Magnolia Springs and 5 cages at Fastrill in late August 1977 and removed in October at cone harvest. These cages contained both cones and conelets. Eggs were oviposited in two cages and several third or fourth instar nymphs were removed from each of these cages at cone harvest. Through November 1977 no conelets died in the two cages with nymphs and adults while 8.2 percent of the conelets died in the cages with adults only, and 4.3 percent of the conelets died in the cages without seedbugs. This indicates that no significant conelet mortality was caused by the shieldback seedbug nymphs or adults in the study. The adult shieldback pine seedbugs introduced into cages at Magnolia Springs and Fastrill seed orchards did, however, feed on seeds within cones. A radiographic analysis of caged seed revealed that the adult seedbugs damaged seed at an average rate of 0.95 ± 0.30 seed per bug per day. The seed yields of the 1977 conelets will be analyzed after cone harvest in 1978 to determine the extent of nymphal and adult feeding on ovules in conelets during late summer.

Effectiveness of Guthion® in Seed Orchards

In the fall of 1977, samples of harvested cones from three East Texas seed orchards and one slash pine seed production area were inspected for coneworm (*Dioryctria* spp.) damage. One slash pine seed orchard and one loblolly pine seed orchard were treated with several applications of the insecticide azinphosmethyl (Guthion®) during 1977 while another loblolly pine seed orchard and the slash pine seed production area were left untreated. The percentages of cones damaged by coneworms were as follows:

High wood specific gravity slash pine seed orchard .... (treated) 18%

Drought hardy loblolly pine seed orchard .... (treated) 9%

Slash pine seed production area .... (untreated) 34%

High wood specific gravity loblolly pine seed orchard .... (untreated) 15%.

These results suggest that coneworms attacked higher percentages of slash pine cones than loblolly pines cones. Coneworm damage in treated orchards was reduced to half that in untreated orchards for both pine species.

Samples of apparently sound cones were further analyzed in order to compare the seed efficiencies for Guthion® treated and untreated cones. In addition to the seed extraction and analysis described in the impact study, the number of first and second year aborted ovules and the seed potential per cone were estimated from dissections of sample cones.

The results of this analysis are summarized in Table 8. The average seed efficiencies (the proportion of the potential seed which developed into apparently sound seed) for cones from the Guth-

Table 8. 1977 Seed Efficiencies for Three Texas Forest Service Seed Orchards at Magnolia Springs.

	High wood specific gravity slash pine (Guthion®)[1]		High wood specific gravity loblolly pine (no control)		Drought-hardy loblolly pine (Guthion®)[1]	
Seed potential/cone	177.4	(77)[2]	155.3	(76)	153.7	(44)
First year aborted ovules/cone	29.9	(77)	61.1	(76)	32.8	(44)
Second year aborted ovules/cone	12.2	(234)	11.3	(229)	9.4	(132)
Total seeds/cone	138.2	(234)	78.6	(229)	107.2	(132)
Full seeds/cone	112.6	(234)	41.9	(229)	82.7	(132)
Seedbug damaged seeds/cone	4.5	(234)	13.7	(229)	5.1	(132)
Percent full seed extracted	89.6%[a]		81.4%[b]		89.8%[a,b]	
Seed efficiency	63.4%[a]		26.7%[b]		53.6%[a]	

[1]Orchard treated with Guthion® five times at monthly intervals during both 1976 and 1977 growing seasons.

[2]Number of cones analyzed.

[a,b]Average percentages not followed by the same letter are significantly different at $P < 0.01$.

ion® treated orchards were approximately twice that of cones from the untreated orchard. Most of the increased seed efficiency for the treated cones can be accounted for in the reduction of aborted ovules during the first year of seed development. Much of the decrease in first year aborted ovules in treated cones is believed to be due to the chemical control of seedbugs. Most of the remaining increase in seed efficiency for treated cones is accounted for by a lower level of seedbug damage in fully developed seed. Also, the full seed extraction efficiencies (full seeds extracted per cone/total full seeds per cone) of the cones from the treated orchards were nearly 10 percent higher than that for the untreated orchard.

In addition to increased seed yields per cone in the treated orchards, cone yields also may have been greater due to reductions in insect-caused conelet and cone mortality. Cone yields, however, were not monitored in this analysis. In conclusion, the Guthion® spray applications in the drought hardy loblolly and high wood specific gravity slash pine seed orchards at Magnolia Springs apparently decreased insect damage and consequently increased the 1977 seed yields.

Light Trap Used to Monitor Cone and Seed Pests

The flight periods of several lepidopterous insects known to damage pine cones and seeds were observed with use of a light trap located adjacent to a loblolly pine stand in Lufkin (Fig. 16). The trap, which attracts and captures night-flying insects, was operated twice weekly from late March through November during 1976 and 1977. Three species of coneworms, tentatively identified as *Dioryctria amatella, D. clarioralis* and *D.* new species (*zimmermani* group) and one species of seedworm, *Laspeyresia toreuta*, were collected.

Large numbers of *D. clarioralis*, up to 182 specimens in one night's collection, were captured during three distinct periods, with peaks in April, July and September in 1977 (Fig. 17). Relatively small numbers of the other species were collected. Peak catches of *D. amatella* were less distinct, but appeared to coincide with those of *D. clarioralis*. One emergence period was observed for *Dioryctria* new species (*zimmermani* group) from late August to early October. Similarly, the seedworm *L. toreuta* was collected only during a single interval from late May to early June. The 1977 peak collection period for each of these four species coincided with those of the previous year, but the numbers caught in 1977 greatly exceeded those in the 1976 collections.

Figure 16. Light trap used to collect night-flying cone insects. The trap is raised into the crown of a selected pine tree prior to night fall and captured insects are collected for identification the following morning.

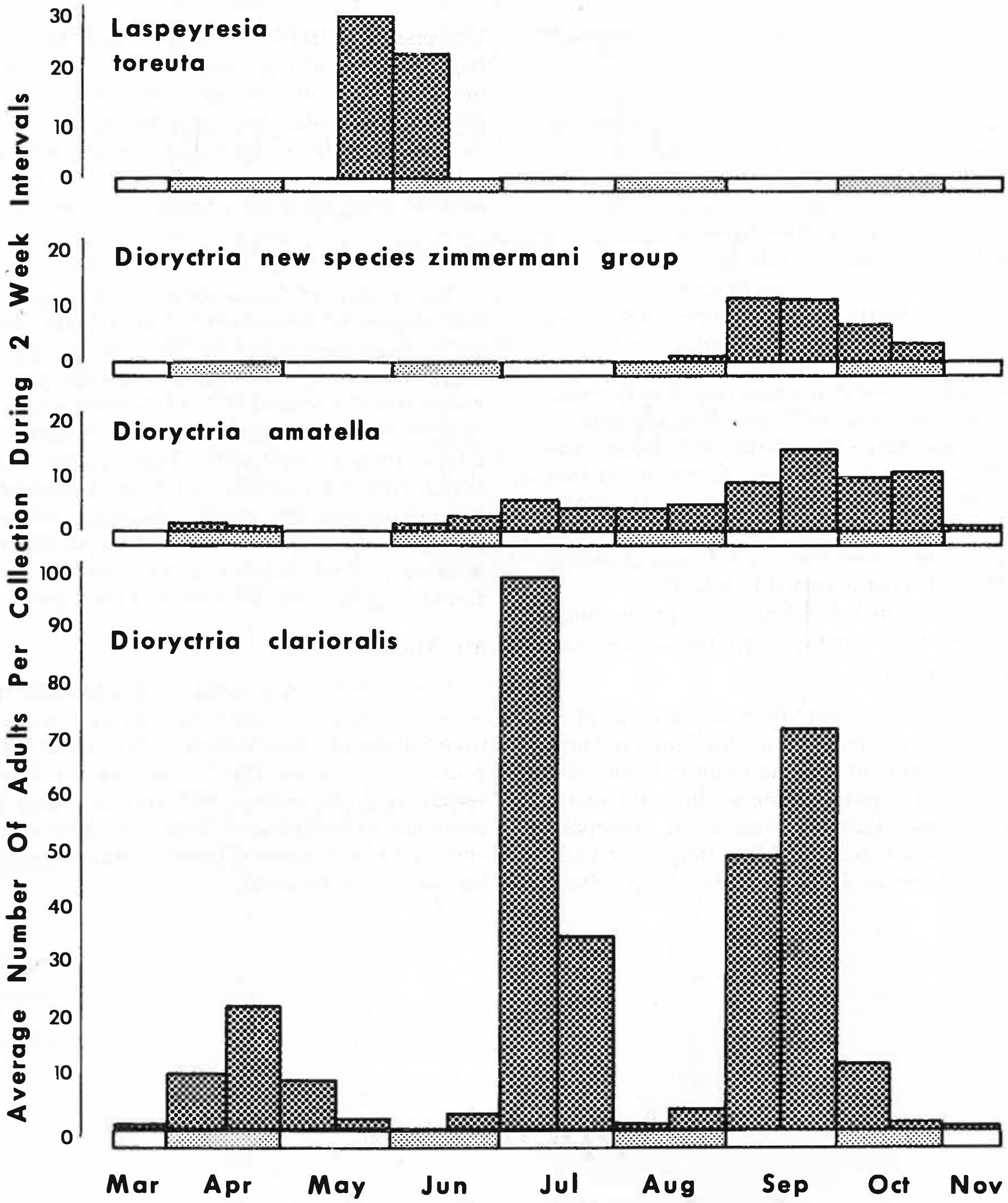


Figure 17. Light trap collections of *Dioryctria* spp. and *Laspeyresia toreuta* during 1977. Lufkin, Texas.

Pest Control Staff

At present, the Forest Pest Control Section staff consists of the following members:

Dr. Ronald F. Billings — Principal Entomologist
Dr. Barry G. Hynum — Entomologist III
Mr. Herbert A. Pase III — Entomologist II
Mr. R. Scott Cameron — Entomologist II
Mr. William F. Rose III — Forester
Mrs. Eva P. Fagala — Technician I
Mr. Michael R. Jeter — Technician I
Mr. F. Alan Smith — Aide to Specialist
Mrs. Martha L. Johnson — Clerk II

A number of staff changes occurred in the Section during 1976 and 1977. Dr. Roy Hedden, a member of the staff since March 1975, left in August 1976 to join Weyerhaeuser Company in Hot Springs, Ark. Forester Charles Kibbe transferred to the Texas Forest Service District 11 office in Kountze in September 1977, and Seasonal Assistant Rick W. Tucker resigned in July 1977.

Brief biographical sketches of the professional staff members who recently joined the Section are:

Dr. Barry G. Hynum

Barry joined the staff upon completion of a Ph.D. in forest entomology at Washington State University in Pullman. His dissertation involved a mathematical description of the landing and attack sequence of mountain pine beetle in lodgepole pine. He also holds M.S. and B.S. degrees in biology and systems ecology from San Diego State University. He recently spent 13 months in Santiago, Chile, teaching computer programming and doing research on convergent evolution. His competence in statistics and computer science as well as his knowledge of bark beetle behavior is being put to immediate use in Pest Control research projects concerning the southern pine beetle.

Mr. William F. Rose III

Bill, a native of Texas, obtained a Master of Forestry degree from Stephen F. Austin State University in Nacogdoches in May 1977, following a B.A. degree in biology from Trinity University in San Antonio and a second B.A. in German and Social Science from Southern Methodist University in Dallas. Prior to joining the Pest Control staff in March 1978, Bill worked as a forestry technician for Weyerhaeuser Company in Oregon. As a research forester with the Section, Bill will be providing assistance to Barry Hynum in field and laboratory research concerning the southern pine beetle.

Mr. Michael R. Jeter

Mike was raised in Dallas and holds a bachelor of science degree in both biology and chemistry from Stephen F. Austin State University in Nacogdoches. He joined the Section as an Aide to Specialist in September 1977 and has since been promoted to Technician I. Mike is working on cone and seed insect research projects, under the direction of Scott Cameron.

Appendices

Texas Forest Service Reorganization

On September 1, 1977, the Texas Forest Service underwent a reorganization to better serve the public. Basically, the former District designations have been changed to Area, and the sub-districts have been changed to Districts. The old District 5 office in Kirbyville has been included under the new Area IV office in Woodville. The present Area/District boundaries are shown on page 28. With additional offices in operation, it should be more convenient for landowners to consult foresters for protection problems and other forestry needs.

Appendix I. Texas Forest Service Area and District Offices

Area	District	Forester	Address	Telephone
I		Steve Adams	P.O. Box 469, Linden, TX 75563	(214) 756-5571
	1	Fred Carrington	P.O. Box 469, Linden, TX 75563	(214) 756-5571
	2	Ken Conaway	P.O. Box 149, Gilmer, TX 75644	(214) 843-3921
	3	Lin Risner	601 Pinecrest Dr. W., Marshall, TX 75670	(214) 938-8712
II		Joe Fox	P.O. Drawer 792, Henderson, TX 75652	(214) 657-4033
	4	Dave Skove	P.O. Box 1783, Jacksonville, TX 75766	(214) 586-1926
	5	John Hale	P.O. Box 195, Carthage, TX 75633	(214) 693-6865
III		Bobby Young	P.O. Box 310, Lufkin, TX 75901	(713) 632-7745
	6	Conrad (Bud) Arnold	701 A South Fourth, Crockett, TX 75835	(713) 544-7798
	7	Ernest Smith	P.O. Box 814, Nacogdoches, TX 75961	(713) 564-9276
	8	Gary Lacox	P.O. Box 968, Center, TX 75933	(713) 598-2192
IV		George Alders	P.O. Box 336, Woodville, TX 75979	(713) 283-3785
	9	Donald Staples	508 Pan American Dr., Livingston, TX 77351	(713) 327-4832
	10	Ron Dosser	P.O. Drawer 280, Kirbyville, TX 75956	(713) 423-2890
	11	Charles Richards	P.O. Box 146, Kountze, TX 77625	(713) 246-2484
V		Jim Blott	Route 7, Box 151, Conroe, TX 77301	(713) 273-2261
	12	Dave Philson	Route 7, Box 151, Conroe, TX 77301	(713) 273-2261
	13	Jim Vaughn	P.O. Box FF, Brenham, TX 77833	(713) 836-3695
	14	John Stine	P.O. Drawer G, La Grange, TX 78945	(713) 968-5556

Appendix II. County Summary of 1976 - 1977 Spot Infestation[1]

	Spots detected		Spots/1000 ac. in 1976	Spots controlled		Spots outstanding[2]	
	1976	1977		1976	1977	1976	1977
Anderson	206	26	1.5	113	9	3	3
Angelina	429	97	1.4	253	26	33	6
Bowie	62	94		41	77	17	8
Camp	1	--		--	--	1	--
Cass	28	--		11	--	3	--
Chambers	50	16		8	2	32	--
Cherokee	419	97	1.9	238	38	15	6
Gregg	57	5		22	2	16	--
Grimes	122	26		10	3	23	1
Hardin	1425	765	5.2	701	493	307	48
Harris	410	59	4.4	22	6	207	2
Harrison	241	118		113	48	9	2
Houston	162	22		24	6	9	2
Jasper	893	347	2.5	334	164	335	66
Jefferson	62	19	4.9	11	7	21	2
Liberty	990	467	6.9	444	243	339	39
Madison	1	--		--	--	--	--
Marion	41	28		13	4	3	4
Montgomery	1059	506	2.5	167	85	435	62
Morris	5	1		1	--	--	--
Nacogdoches	298	84	1.3	131	31	36	2
Newton	417	107	1.2	188	55	105	13
Orange	267	137	5.1	68	46	141	3
Panola	152	55		85	27	40	4
Polk	894	374	1.8	466	291	147	12
Red River	76	38		34	4	33	6
Rusk	158	45		97	18	18	1
Sabine	144	55		57	10	42	12
San Augustine	133	91		67	30	24	4
San Jacinto	209	51		54	19	91	9
Shelby	212	196		80	26	20	3
Smith	57	1		2	--	27	--
Trinity	254	33		147	17	20	4
Tyler	626	284	1.7	212	154	129	38
Upshur	67	7		16	4	31	1
Walker	236	62	0.9	35	6	31	4
Waller	36	11		7	5	9	--
Wood	12	1		--	1	8	--

[1]Spots reported inactive may be calculated by subtracting spots controlled and spots outstanding from spots detected.
[2]Require ground check or control at end of year.

TEXAS FOREST SERVICE